PB-217 704

PERFORMANCE TESTS FOR PLATE HEAT EXCHANGERS USED FOR ULTRA-HIGH-TEMPERATURES PASTEURIZATION PROCESSES

R.W. Dickerson, Jr., et al

Enviromental Control Administration
Cincinnati, Ohio

1968

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

ENVIRONMENTAL CONTROL ADMINISTRATION

PB 217 704
LIBRARY
Environmental Control Administration
5555 Ridge Ave., Cincinnati, O. 45213

PERFORMANCE TESTS FOR PLATE HEAT EXCHANGERS USED FOR ULTRA-HIGH-TEMPERATURE PASTEURIZATION PROCESSES

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. Department of Commerce
Springfield VA 22151

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service

PERFORMANCE TESTS FOR PLATE HEAT EXCHANGERS USED FOR ULTRA-HIGH-TEMPERATURE PASTEURIZATION PROCESSES

R. W. Dickerson, Jr.
R. B. Read, Jr.
H. E. Thompson, Jr.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service
Environmental Control Administration
Environmental Sanitation Program
Cincinnati, Ohio 45202
1968

I

CONTENTS

ABSTRACT v
INTRODUCTION 1
MEASURING HOLDING TIME 1
Calculation of Holding Tube Length 2
Measuring the Length of the Holding Tube 5
MEASURING CONTROL RESPONSE TIME 6
Control Response Time Less Than Holding Time . . . 6
Control Response Time Greater Than Holding Time . 6
SUMMARY 10
ACKNOWLEDGMENT 10
REFERENCES 11
APPENDIX 13
TESTS FOR ULTRA-HIGH-TEMPERATURE EQUIPMENT 13
Test No. 12. Continuous Flow Holders-Holding Time 13
Test No. 13. Thermometric Lag of Recorder-Controller 15
Test No. 14. Adjustment of Diversion Time-Delay Relay 15
Test No. 15. Diversion Temperature Setting When Control Response Time is Greater Than the Holding Time 17

ABSTRACT

Most of the tests employed to measure the performance of ultra-high-temperature pasteurizers are the same as those used for high-temperature, short-time pasteurizers; the only changes are in the procedures for measuring holding time and the speed of response of the control system. Methods for measuring holding time and control response time are presented in the same format as those recommended in the Public Health Service's Grade "A" Pasteurized Milk Ordinance.

INTRODUCTION

Time-temperature standards for ultra-high-temperature (UHT) pasteurization of milk and milk products have been identified by the U.S. Public Health Service[1] as equally efficient as and supplemental to those processes described in the 1965 Grade "A" Pasteurized Milk Ordinance.[2] The standards consist of holding times of 1, 0.5, 0.1, 0.05, and 0.01 second for temperatures of 191, 194, 201, 204, and 212°F, respectively. The tests described in the Grade "A" Pasteurized Milk Ordinance for high-temperature, short-time pasteurizers are applicable to ultra-high-temperature equipment except for modification of the procedures used for timing the holding tube and determining the speed of response of the recorder-controller flow-diversion valve system. The objective of this paper is to describe the procedures for measuring holding time and speed of response of the control system.

MEASURING HOLDING TIME

Because of viscosity, product particles move through a holding tube with different velocities and, hence, different residence times; yet, every particle must be held in the holding tube for at least the minimum holding time required for pasteurization. With milk, this is accomplished by measuring the residence time of a salt tracer in water and by using this as the minimum residence time in the holding tube. The measurement is an accurate one for milk, but is inaccurate for ice cream mix[3] because of a change in flow profiles from turbulent flow with water and milk to laminar flow with ice cream mix. The greatest variation in residence times of product particles occurs with laminar flow,[4] and consequently the holding tube should be sized to hold the fastest moving particle in laminar flow for the minimum time required for pasteurization. Fortunately, the characteristics of laminar flow are well-known[4] both experimentally and theoretically, and holding-tube length may be accurately calculated from the equation[4]

$$L = 588 \frac{Qt}{D^2} \qquad (1)$$

where L = holding-tube length (inch)
Q = pumping rate (gallon per second)
t = holding-time standard (second)
D = inside diameter of holding tube (inch).

Calculation of holding-tube length. With the use of Equation 1, holding-tube lengths were calculated for a pasteurizer operating at a flow rate of 1 gallon per second (Table 1), and these data may be used to

Table 1. HOLDING TUBE LENGTHS FOR UHT PASTEURIZATION WITH A PUMPING RATE OF 1 GALLON PER SECOND

UHT standard		Holding tube length, inches				
Time, seconds	Temperature, °F	Tubing size (outside diameter), inches				
		1	1-1/2	2	2-1/2	3
1.0	191	723	300	168	105	71.4
0.5	194	362	150	84	52.4	35.7
0.1	201	72.3	30	16.8	10.5	7.14
0.05	204	36.2	15	8.4	5.24	3.57
0.01	212	7.23	3	1.68	1.05	0.714

calculate the required holding-tube length for any flow rate. This is accomplished by determining the time required for the pasteurizer to fill a vessel of known volume, converting these data by division to obtain flow rate in gallons per second, and multiplying this value by the applicable number in Table 1 to obtain the required length of holding tube for the process. Although better sealing characteristics (at the metering pump) and, hence, faster pumping rates are obtained with product, the pasteurizer can be operated with water to obtain the data needed to make a calculation of holding-tube length, because the increased flow rate with product is compensated by the deviations from fully developed laminar flow found in all pasteurizers. The effect of laminar flow is reflected in the values given in Table 1 and need not be considered in field calculations. All calculations follow the equation

$$A = B \times C \qquad (2)$$

where A = holding-tube length (inch)

B = measured pumping rate (gallon per second)

C = holding-tube length from Table 1 (inch).

The following examples illustrate the use of Table 1 and Equation 2.

Example 1:

The control authority, or processor, chooses the UHT standard and flow rate and wants to know the required length of holding tube.

The pasteurizer has a nominal capacity of 10,000 pounds per hour, and the time to fill a 10-gallon can with water from the pasteurizer is 32.5 seconds. The chosen standard is 204°F for 0.05 second, and the holding tube is 2 inches in diameter. Pumping rate is 10 gallons divided by 32.5 seconds, which is 0.308 gallon per second.

The required holding-tube length, A, is calculated from Equation 2 ($A = B \times C$). The pumping rate, B, is 0.308 gallon per second, and from Table 1, the holding-tube length, C, required for a holding time of 0.05 second with a pumping rate of 1 gallon per second in 2-inch-diameter tubing is 8.4 inches. For this example,

$$A = 0.308 \times 8.4$$

and

$$A = 2.6 \text{ inches}$$

so the holding tube must be at least 2.6 inches long.

Example 2:

The control authority, or processor, chooses holding-tube length and pumping rate and wants to know the required UHT standard.

The pasteurizer has a nominal capacity of 2,000 pounds per hour, and the time to fill a 10-gallon can with water from the pasteurizer is 2 minutes

and 12 seconds. The holding tube is 1-1/2 inches in diameter and 18 inches long. Pumping rate is 10 gallons divided by 132 seconds, which is 0.0758 gallon per second. Before a UHT standard can be identified from Table 1, the value of C must be calculated from Equation 2 ($A = B \times C$). The pumping rate, B, is 0.0758 gallon per second and the chosen holding tube length, A, is 18 inches. Therefore,

$$18 = 0.0758 \times C$$

or

$$C = \frac{18}{0.0758}$$

and $C = 238$ inches.

From Table 1, for a tube diameter of 1-1/2 inches, this holding-tube length falls between standards of 191°F for 1 second and 194°F for 0.5 second. Since the holding tube is too short for a 1-second holding time, the 0.5-second standard must be used with a holding temperature of 194°F. Obviously, the standard of 191°F for 1 second could be used by increasing the length of the holding tube, or reducing pumping rate, or both.

Example 3:

The control authority, or processor, chooses the UHT standard and holding-tube length and wants to know the maximum permissible pumping rate.

The pasteurizer has a nominal capacity of 60,000 pounds per hour, and the chosen standard is 204°F for 0.05 second. The holding tube is 3 inches in diameter and 6 inches long. The pumping rate is calculated from Equation 2 ($A = B \times C$). The holding-tube length, A, is 6 inches, and from Table 1, the holding-tube length, C, required for a holding time of 0.05 second with a pumping rate of 1 gallon per second in 3-inch-diameter tubing is 3.57 inches. For this example

$$6 = B \times 3.57$$

or

$$B = \frac{6}{3.57}$$

and $B = 1.68$ gallons per second

Therefore, the maximum permissible pumping rate is 1.68 gallons per second. At this pumping rate, the time required to fill a 100-gallon vat is 100 gallons divided by 1.68 gallons per second, or 59.5 seconds.

Measuring the length of the holding tube. After the minimum required holding-tube length is obtained from the calculation above, the length of the holding tube is measured to determine that it is at least as long as the calculated length. The holding tube may include fittings or, for the shorter holding times, may be a fitting. The centerline length of the fitting is treated as an equivalent length of straight pipe. A number of fittings are standardized by the 3-A Committees,[5,6] and their centerline distances are fixed (Table 2). For fittings that are not standardized, the centerline distance may be measured by forming a flexible steel tape along the centerline of the fitting.

Table 2. CENTERLINE DISTANCES OF 3-A APPROVED[a] SANITARY FITTINGS

3-A Designation	Centerline distance, inches				
	Fitting size, inches				
	1	1-1/2	2	2-1/2	3
2 C 90° bend[b]	3.4	4.8	6.2	8.0	9.7
2 CG 90° bend[b]	3.1	4.5	5.8	7.6	9.3
2 F 90° bend	3.4	4.8	6.2	8.0	9.7
2 FG 90° bend	3.4	4.8	6.2	8.0	9.7
2 E 90° bend	3.4	4.8	6.2	8.0	9.7
2 EG 90° bend	3.2	4.6	6.0	7.7	9.4

[a]Sanitary Standards for Fittings Used on Milk and Milk Products Equipment and Used on Sanitary Lines Conducting Milk and Milk Products.[5,6]

[b]The designation 2 C identifies a bevel seat fitting; 2 CG identifies a gasket seat fitting.

MEASURING CONTROL

RESPONSE TIME

Control response time is defined as the elapsed time between passage of the first portion of underheated product over the temperature sensing element of the control system and closure of the forward-flow port of the flow-diversion valve.

Thus, control response time is the sum of the thermometric lag of the recorder-controller and the response time of the flow-diversion valve. Two general approaches are applicable to the measurement of control response time of UHT pasteurizers: in one, the control response time is the same or less than the holding time, and in the other, the control response time exceeds the holding time.

Control response time less than holding time. For a process with a 1-second holding time and the temperature sensing element of the control system at the beginning of the holding tube, the control response time must be 1 second or less to prevent, in the case of process failure, underheated product from getting through the flow-diversion valve before it is in diverted flow. Controls with a response time of 1 second or less, including controls with negative response times (controllers with rate mode),[7] are feasible with modern instrumentation and would be satisfactory for the control of UHT processes provided (a) the response time was equal to or less than the holding time, (b) the temperature sensing unit was at the beginning of the holding tube, (c) the holding tube was protected so that liquids such as water used for rinsing the outside of the press during operation could not come into direct contact with the holding tube, and (d) the controls were suitably adjusted so that the time required to go from diverted to forward flow would exceed the holding time. To comply with provision (c), the holding tube may be insulated with a moisture-proof insulation, such as ARMAFLEX.[a] To comply with provision (d), a time-delay relay is installed between the recorder-controller and the flow-diversion valve.

Control response time greater than holding time. When provision (a) cannot be met and the control response time exceeds the holding time, the diversion

[a]Trademark of the Armstrong Cork Co., Lancaster, Pa. Mention of commercial products does not imply endorsement by the Public Health Service.

temperature of the recorder-controller must be increased above that of the applicable UHT-pasteurization standard so that diversion is completed before the product temperature falls below standard. The proper diversion temperature is obtained by determining the maximum number of degrees Fahrenheit the temperature of the product would fall during the control response time and adding this to the pasteurization standard.

In practice, the number of degrees Fahrenheit to add to the pasteurization standard is determined by taking the number of degrees increase in product temperature that occurs in the heater section during normal operation of the pasteurizer and dividing this by the number of seconds required for product to pass through the heater. This will give the average rate of temperature increase in degrees Fahrenheit per second and, hence, the average decrease on failure of the steam supply to the pasteurizer and, for hot water systems, the simultaneous failure of the hot water pump. This value multiplied by the control response time less the holding time in seconds (the temperature sensing unit is at the beginning of the holding tube) will yield the number of degrees Fahrenheit to add to the appropriate pasteurization standard to obtain the proper diversion setting of the recorder-controller, as follows:

$$T_D = T_S + \frac{T_2 - T_1}{\tau_1} (\tau^* + \tau - t) \qquad (3)$$

where T_D = diversion setting of recorder-controller (°F)

T_S = temperature of the pasteurization standard (°F)

τ_1 = residence time of a salt tracer in the heater (second)

T_1 = minimum temperature at inlet of heater (°F)

T_2 = maximum temperature at exit of heater (°F)

t = holding-time standard (second)

τ^* = thermometric lag of the temperature sensing bulb (second)

τ = response time of the flow-diversion valve (second).

The control response time is the time lag between fluid temperature and sensing bulb (Figure 1) plus the response time of the flow-diversion valve. The time lag of Figure 1 is equal to thermometric lag (time required to respond to 63 percent of a step change),[8] and, therefore, control response time is determined by measuring downscale thermometric lag of the recorder-controller and response time of the flow-diversion valve.

The increase in product temperature through the heater is determined by temporarily installing thermometers at the inlet and exit of the heater section of the UHT pasteurizer and reading the temperatures indicated while the pasteurizer is running at maximum flow and temperature with water as the product. The time required for the product to go through the heater is measured by the salt injection technique with the injection point at the inlet to the heater and the conductivity sensing element at the exit from the heater. Determinations of heating rate and residence time in the heater for a given process need to be made only at initial start-up and whenever flow rate, or plating arrangement, or both are changed.

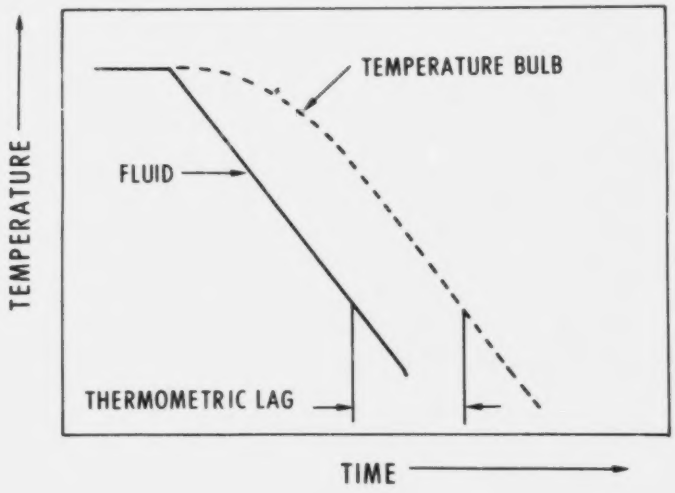

Figure 1. Response of a temperature-sensing element to a linear decrease in temperature.

The use of Equation 3 is illustrated as follows:

A processor is pasteurizing milk using a UHT standard of 201°F for at least 0.1 second, but operating the equipment to yield a final milk temperature of 300°F. The unit has no regeneration section and, therefore, the minimum temperature at the inlet of the heater is 40°F. The residence time of a salt tracer in the heater section is 32 seconds. The thermometric lag of the temperature sensing bulb is 2.8 seconds, and the response time of the flow-diversion valve is 0.2 second. What is the proper diversion setting of the recorder-controller? Substituting in Equation 3

$$T_D = 201°F + \frac{300°F - 40°F}{32 \text{ seconds}} (2.8 \text{ seconds} + 0.2 \text{ second} - 0.1 \text{ second})$$

$$T_D = 201°F + 8.1°F \text{ per second } (2.9 \text{ seconds})$$

$$T_D = 201°F + 23.5°F = 224.5°F$$

In practice, the diversion setting of the recorder-controller would be adjusted to 225°F.

SUMMARY

The tests described in the Grade "A" Pasteurized Milk Ordinance[2] are applicable to UHT equipment with two exceptions: holding time and the response time of the temperature control system. The salt injection technique of timing the holding tube (Test 11 of Reference 2) is replaced by a procedure that identifies the residence time of the fastest moving particle of all milk products (Appendix, Test 12). The method of measuring upscale thermometric lag (Test 8 of Reference 2) is replaced by a test for measuring downscale thermometric lag between 203 and 184°F (Appendix, Test 13).

The only change in equipment arrangement is the location of the sensing bulb of the recorder-controller at the beginning of the holding tube. Because of this, a time-delay relay is used to prevent premature forward flow (Test 14 describes the adjustment of the relay).

When the control response time is greater than the pasteurization standard, the diversion temperature is set above the pasteurization standard so that diversion is accomplished before product temperature falls below standard (Test 15 describes methods of determining the diversion temperature setting).

ACKNOWLEDGMENT

We are grateful for the helpful suggestions of Mr. Harold Faig and for the assistance of Mesdames A. Patterson, Florence Layne and Marion Curry, and Pauline Elliott in typing, editing, and composing the manuscript, respectively.

REFERENCES

1. Read, R. B., R. W. Dickerson, and H. E. Thompson. Time-temperature standards for the ultra-high temperature pasteurization of grade A milk and milk products by plate heat exchange. J. Milk Food Technol. 31:72-74. Mar. 1968.

2. U.S. Public Health Service. Grade "A" pasteurized milk ordinance. 1965 Recommendations of the U.S. Public Health Service. PHS Publ. No. 229. U.S. Govt. Printing Office, Washington, D.C. 1965.

3. Scalzo, A. M., R. W. Dickerson, and R. B. Read. Residence time of milk and milk products in holding tubes of HTST pasteurizers. J. Dairy Sci. 51:930. June 1968.

4. Knudsen, J. G., and D. L. Katz. Fluid dynamics and heat transfer. McGraw-Hill, New York, N. Y., 1958. pp. 86, 149.

5. International Association of Milk and Food Sanitarians, Inc., U.S. Public Health Service, and The Dairy Industry Committee. Sanitary Standards for Fittings Used on Milk and Milk Products Equipment and Used on Sanitary Lines Conducting Milk and Milk Products. International Association of Milk and Food Sanitarians, Inc., Washington, D.C., 1950.

6. International Association of Milk and Food Sanitarians, U.S. Public Health Service, and the Dairy Industry Committee. Supplement No. 3, 4, 5, 6 to the 3-A Sanitary Standards for Fittings Used on Milk and Milk Products Equipment and Used on Sanitary Lines Conducting Milk and Milk Products, J. Milk Food Technol. 18:226-232. Sept. 1955.

7. Forman, E. R. Fundamentals of automatic control engineering. In: Handbook of applied instrumentation, D. M. Considine and S. D. Ross, eds. McGraw-Hill, New York, N. Y. 1964. p. 10.

8. Jakob, M. Heat transfer. John Wiley, New York, N. Y. 1949. p. 183.

APPENDIX

TESTS FOR
ULTRA-HIGH-TEMPERATURE EQUIPMENT

Test No. 12. CONTINUOUS FLOW HOLDERS - HOLDING TIME

APPLICATION - To all UHT pasteurizers with continuous-flow holding tubes.

FREQUENCY - When installed and semiannually thereafter; whenever seal on speed setting is broken; whenever any alteration is made affecting the holding time, the velocity of the flow (e.g., replacement of pump, motor, belt, driver or driven pulley, or decrease in number of heat-exchange plates), or the capacity of holding tube; whenever a check of the capacity indicates a speedup.

CRITERIA - Every particle of product shall be held for the minimum holding time in both the forward- and diverted-flow positions.

METHOD - Fully developed laminar flow is assumed, and holding-tube length is calculated. An experimental determination of pumping rate is required; this is accomplished by determining the time required for the pasteurizer to fill a vessel of known volume, converting these data by division to obtain flow rate in gallons per second, and multiplying this value by the proper number in Table 1 to obtain the required length of holding tube.

TEST PROCEDURE - Examine the entire system to ensure that all flow-promoting equipment is operating at maximum capacity and all flow-impeding equipment is so adjusted or bypassed to provide the minimum of resistance to the flow. This means that in-line filters must be removed, booster pumps must be in operation, and vacuum equipment in the system must be operating at maximum vacuum. Also, before the tests are begun, the pasteurizer should be operated at maximum flow for a sufficient time to purge air from the system (about 15 minutes) and pipe connections on the suction side of the metering pump should be made tight enough

Preceding page blank

to exclude entrance of air. With the pasteurizer operating with water, adjust the metering pump to its maximum capacity (preferably with a new belt and full-size impellers).

Determine that no flow exists in the diverted line, and measure the time required to deliver a known volume of water at the forward-flow discharge line. Repeat the test at least once to determine that the measurements are consistent.

Repeat the above step in diverted flow by collecting the effluent at the discharge of the divert line.

Select the greatest flow rate (shortest delivery time for the known volume) and calculate the flow rate in gallons per minute by dividing the known volume by the time required to collect the known volume; thus, if 2 minutes is required to fill a 10-gallon can, then flow rate is 0.083 gallons per second. Multiply this value with the appropriate value in Table 1 to determine the required holding-tube length.

For pasteurizers of large capacity, the method of measuring flow rate at the discharge of the pasteurizer is inconvenient and the following alternate test procedure may be used. Remove the divert line from the raw-product supply tank, and turn off the product pump feeding the raw-product supply tank. Suspend a sanitary dip stick in the raw-product supply tank, and operate the pasteurizer at maximum capacity. Record the time required for water level to move between two graduations on the dip stick. The volume of water is calculated from the dimensions of the raw-product supply tank and the drop in water level. Flow rate is determined as follows: divide the volume of water removed from the raw-product supply tank by the time required to remove it.

Determine the number and type of fittings in the holding tube and convert these to equivalent lengths of straight pipe with the use of Table 2. Determine the total length of the holding tube by adding the equivalent lengths of the fittings to the measured straight lengths of pipe. Record the number and type of fittings, the number and length of straight pipes, and the holding-tube configuration for the office record. Observe that the holding tube is protected against heat loss. If in-

sulation is used, observe that the insulation is impervious to water.

CORRECTIVE ACTION - If the length of the holding tube is shorter than the calculated length, reseal the metering pump at a slower maximum speed, or lengthen the holding tube, or both, and repeat the above determination.

Test No. 13. THERMOMETRIC LAG OF RECORDER-CONTROLLER

APPLICATION - To all recorder-controllers used to control UHT pasteurization processes.

FREQUENCY - When installed and at least once each 3 months thereafter.

CRITERIA - Thermometric lag plus the response time of the flow-diversion valve shall be less than the holding time except when the diversion temperature setting is set higher than the pasteurization standard, but never exceeding 6 seconds.

METHOD - Using two water baths (10-gallon milk cans) and a stopwatch, measure the time required for the recorder-controller to respond to 63 percent of a downscale step change in temperature.

TEST PROCEDURE - If necessary, adjust the pen-arm setting of the recorder-controller to agree with the indicating thermometer at pasteurization temperature. Heat one water bath to a temperature of 203°F and the other to 184°F. Immerse the temperature-sensing element in the 203°F bath, and agitate the bath vigorously (the recorder-controller should indicate 203°F). Move the agitator to the 184°F bath, and while agitating vigorously, rapidly transfer the temperature-sensing element to the 184°F bath. Start the stopwatch the instant the temperature-sensing element leaves the 203°F bath, and stop the stopwatch the moment the recorder-controller indicates 191°F. Record thermometric lag (time interval from stopwatch) for the office record.

Test No. 14. ADJUSTMENT OF DIVERSION TIME-DELAY RELAY

APPLICATION - To all recorder-controllers used to control UHT pasteurization processes where the

control response time is less than the holding time and the diversion point is adjusted to the pasteurization standard.

FREQUENCY - When installed and at least semiannually thereafter; whenever holding tube length is changed.

CRITERIA - The temperature-sensing bulb of the recorder-controller shall be located at the beginning of the holding tube and a time-delay relay installed and adjusted so that, during increasing temperatures, the time delay between forward flow at the recorder-controller and forward flow at the flow-diversion valve shall be at least 1 second longer than the maximum residence time between the temperature-sensing element and the flow-diversion valve at the minimum pumping rate of the pasteurizer. During decreasing temperatures, the time-delay relay shall not delay the diversion movement.

METHOD - The required time delay is that occurring during the minimum pumping rate of the pasteurizer. This value is determined by multiplying the average residence time of milk in the holding tube by the ratio of maximum to minimum pumping rate.

TEST PROCEDURE - Observe that the temperature-sensing element is located at the beginning of the holding tube. With the pasteurizer operating on water, record the maximum and minimum pumping rates and observe that the metering pump has been sealed at both pumping rates. With the use of the maximum and minimum pumping rates, calculate the time delay as follows:

$$\text{Time delay} = 2\,t\,\frac{\text{maximum pumping rate}}{\text{minimum pumping rate}} + 1 \text{ second}$$

where t is the pasteurization-time standard and is equal to the residence time of the fastest particle. The factor of 2 yields the residence time of the average particle. Operate the pasteurizer on water (at any speed between the minimum and maximum settings of the metering pump) at a tempera-

ture below the diversion setting. Increase operating temperature to cause a forward-flow movement, and record the elapsed time between forward flow at the recorder-controller and forward flow at the flow-diversion valve. With the pasteurizer operating above the diversion temperature, decrease operating temperature to cause a diversion movement. Observe that the time-delay relay does not delay the diversion movement.

CORRECTIVE ACTION - If the time delay is too short, readjust the time-delay relay.

ALTERNATE METHOD - All UHT-holding-time standards are 1 second or less and, furthermore, a metering pump cannot be operated at less than one tenth of its maximum capacity. Consequently, the time delay need be no greater than 20 seconds. Accordingly, a delay of 20 seconds may be used in lieu of the above test procedure.

Test No. 15. DIVERSION TEMPERATURE SETTING WHEN CONTROL RESPONSE TIME IS GREATER THAN THE HOLDING TIME

APPLICATION - To all UHT pasteurizers with continuous-flow holding tubes and a control response time greater than the holding time.

FREQUENCY - When installed; whenever maximum flow rate, plating arrangement, or both are changed.

CRITERIA - The diversion temperature of the recorder-controller shall be adjusted above that of the UHT standard so that, during the fastest rate of temperature decrease, diversion is complete before temperature falls below standard.

METHOD - The maximum rate of temperature decrease is multiplied by the control response time, and this yields the number of degrees Fahrenheit to be added to the pasteurization standard. The rate of temperature decrease is identical to the rate of temperature rise in the heater section; this is determined by measuring the temperature at the inlet and at the exit of the heater section and the residence time, by the salt injection technique, of the fastest particle passing through the heater.

TEST PROCEDURE - Install an indicating thermometer and salt conductivity electrode at the inlet and exit of the heater section. Operate the pasteurizer on water, and examine the entire system to ensure that all flow-promoting equipment is operating at maximum capacity and all flow-impeding equipment is adjusted or bypassed to provide the minimum resistance to flow.

Move the process temperature control to its maximum adjustment, and after the temperatures have stabilized in forward flow, record the temperatures at the inlet and exit of the heater. With the pasteurizer in forward flow, inject a salt tracer at the heater inlet and record the residence time of the tracer as it passes through the heater. Repeat the tests until 6 successive readings are within 0.5 second of each other.

Divide the temperature rise through the heater by the residence time in the heater to obtain the maximum rate of decrease in degrees Fahrenheit per second. Measure thermometric lag and response time of the flow-diversion valve (Test 13 of this Appendix and Test 8 of Reference 2), and add these values to obtain control response time. Multiply the rate of temperature decrease with the control response time to obtain the maximum temperature drop preceding a diversion movement. Add this temperature difference to the UHT standard, and adjust the diversion temperature of the recorder-controller to the higher setting.

U.S. GOVERNMENT PRINTING OFFICE - 1968 O - 321-472